Utrecht University

M.A. Linguistics
Master Thesis

Mediating factors in predictive language processing: an EEG study on the effects of working memory, inhibitory control and processing speed.

Arnold R. Kochari
4049098

August 2015

Supervisor: dr. Monique Flecken, Neurobiology of Language Department, MPI for Psycholinguistics
Second supervisor: prof. dr. Jos van Berkum, Utrecht Institute of Linguistics OTS

Acknowledgments

This thesis is a report on a small portion of a big and exciting project which I have had the fortune of working on over the last half a year, under the supervision of Monique Flecken at the Neurobiology of Language Department of MPI for Psycholinguistics. Unfortunately, at the time of submission for report, it was not yet possible for me to complete the project as originally intended, or to even fully explore the data that is now being presented. This report should rather be seen as an intermediate stage of progress and I look forward to continuing my work on this project. I would like to thank the department for accepting me for an internship and for granting me use of the lab. I am tremendously grateful to Monique for teaching me the skills which have allowed me to collect and analyze the data. I have learnt a lot during the time I have spent at NBL, and I look forward to learning more in our future collaboration.

Submitting this, I am graduating from my master's program at Utrecht University. The two years that I have spent studying here were demanding, but also very rewarding. I would never have imagined that I could learn so much in so little time. This would not have been possible were it not for the knowledgeable and inspiring teachers and supervisors that I have had during my time here. I am very grateful for all that they have taught me, and I hope to make use of this knowledge by conducting good quality research in the future. I am glad that I chose Utrecht Institute of Linguistics.

Last but not least, my studies in Utrecht were fully funded by Utrecht Excellence Scholarship sponsored by Utrecht University and the alumni fund of the university. Without their support, I would not be able to come to the Netherlands to study, and I would therefore like to thank them for making these amazing two years in Utrecht possible.

Recent findings in language comprehension research suggest that there might be important individual differences in the extent to which individuals engage in predictive sentence processing. The study reported here employed EEG to investigate the effects of individual differences in working memory capacity (as measured by digit span task), inhibitory control ability (as measured by flanker task) and processing speed (as measured by symbol substitution task) on predictive processing. Specifically, we looked at the predictability effect at a gender-marked determiner preceding a highly predictable noun. We obtained an overall negative deflection in ERPs in the processing of the unexpected determiner in comparison to an expected one. The individual differences, however, did not modulate the size of this effect. Possible reasons for the lack of such modulation by individual differences are discussed.

1. Introduction

The past decade of research into different aspects of human cognition has revealed an important role of anticipatory processing by the brain. It has been experimentally demonstrated at the levels of both neural responses and behavior that we predict the outcome of the actions of other people and the environment around us as we see these events unfold (Clark, 2013 for a review). Predictive processing has been actively investigated in language comprehension research as well, and the results suggest that we anticipate a variety of properties of the upcoming linguistic input. The evidence suggests that while listening to speech or reading we predict semantic features of the words that are upcoming (Federmeier & Kutas, 1999) as well as more detailed information about specific word forms, such as their phonological (DeLong, Urbach, & Kutas, 2005; Martin et al., 2013) and orthographic form (Dikker, Rabagliati, Farmer, & Pylkkänen, 2010; Laszlo & Federmeier, 2009), syntactic category (Dikker, Rabagliati, & Pylkkänen, 2009; Kim & Gilley, 2013; Lau, Stroud, Plesch, & Phillips, 2006) and morphosyntactic features (Van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005; Wicha, Moreno, & Kutas, 2003, 2004). These predictions can be made and adjusted based on, for example, real-world knowledge, (morpho)syntactic information in the preceding part of the sentence, or prosody. In addition, the ability to predict upcoming words has also been demonstrated to correlate with language development in children (Borovsky, Elman, & Fernald, 2012; Mani & Huettig, 2012; Nation, Marshall, & Altmann, 2003). In light of these findings, predictive processing has been attributed a central role in language comprehension, production and learning (e.g. Altmann & Mirković, 2009; Pickering & Garrod, 2013).

However, recent findings suggest that not everyone may be engaging in predictive processing during language comprehension to the same extent and that it can differ in different communication situations (see Huettig, (in press) for a review). For example, older people show smaller effects of contextual constraint during online sentence comprehension and it has been suggested that they rely on predictive processing less (Federmeier, Kutas, & Schul,

2010; Wlotko & Federmeier, 2012; Wlotko, Federmeier, & Kutas, 2012; but see Janse & Jesse, 2014). It has also been found that literacy plays a role – in a study by Mishra and colleagues (Mishra, Singh, Pandey, & Huettig, 2012) low literate adults did not show anticipatory eye movements in the way high literate adults did. Another type of language user that has been attributed a reduced predictive ability is the second language speaker (Foucart, Martin, Moreno, & Costa, 2014; Kaan, 2014; Martin et al., 2013). Finally, it is not only the speakers' background, but also differences in general cognitive abilities that can modulate predictive processing. Recent studies suggest that working memory capacity and processing speed may modulate the extent to which a person engages in predictive processing (Huettig & Janse, 2015; Janse & Jesse, 2014). Modulation of predictive processing by individuals' cognitive capacities is what we would like to investigate further in the current study.

Findings suggesting that certain populations may be engaging in predictive processing less are not surprising given that, in natural communication situations, predictions have to be quickly formed and filtered as the new information is being processed. There have recently been multiple attempts to form theories of language production and comprehension with a role for predictive processing embedded in them (e.g. Altmann & Mirković, 2009; Dell & Chang, 2014; Jaeger & Snider, 2013; Pickering & Garrod, 2013). In order for these theories to capture the processes that take place in the brain, they also have to account for differences in predictive ability depending on individual differences in cognitive capacities.

The current study aims at exploring the (inter)dependence of predictive processing and individual differences in working memory capacity (WMC), processing speed, and inhibition of irrelevant information using electroencephalography (EEG). The results of this study would support or cast doubt on previous findings regarding WMC and processing speed using a different methodology and design, as well as extend the body of research to another individual difference that is predicted to be of relevance - inhibitory control ability. Below, each of the measured individual differences will be defined, and discussed in terms of their relevance for predictive processing and the findings to date.

Working memory

Broadly defined, working memory (WM) refers to the ability to temporarily store pieces of information that are relevant for the current processing task and manipulate and use them in this processing (Baddeley, 2003; MacDonald & Christiansen, 2002; Miyake & Shah, 1999). Working memory is suggested to have a limited capacity – a limited amount of information can be stored and processed. A large body of research suggests that individuals differ in their working memory capacity and that this is correlated with some differences in processing language input (e.g. Bornkessel, Fiebach, & Friederici, 2004; Daneman & Carpenter, 1983; Gathercole & Baddeley, 2014; Just & Carpenter, 1992; Just, Carpenter, & Keller, 1996; Vos, Gunter, Kolk, & Mulder, 2001). The ability to store and manipulate information should be relevant for predictive processing, because prediction involves making inferences based on the currently known information that needs to be stored and processed online before the next

chunk of information comes. During language comprehension, the meanings of the incoming words, and the concepts that automatically come together with them (for example, if someone refers to a 'student', this person is going to lectures, is likely to be young and unmarried) have to be stored in memory, or, in different terms, a situation model based on the information given so far needs to be built and stored (Zwaan & Radvansky, 1998)) in order for this semantic information to be integrated with the information on the upcoming words (although it has to be noted that such situation models do not have be stored in working memory as it is defined here – see e.g. Eriksen & Kintsch (1995), Eriksen & Delaney (1999) for a different view). This is assumed to be resource-demanding and if an individual has more resources to store information and make it readily available, it is possible that she is more likely to make an inference that would serve as a prediction.

One piece of evidence supporting the importance of working memory capacity for predictive processing comes from eye-tracking reading studies. Several studies (e.g. Calvo, 2001; Estevez & Calvo, 2000) show that individuals with high working memory span are better and faster at making inferences from previous sentences that help them read the following event or name a picture related to the predicted event. For example, upon reading about a student that goes to a library, high working memory capacity individuals were more efficient at making an inference that she studied there (Calvo, 2001).

A recent large eye-tracking study with over a hundred participants across all ages has also found a correlation between predictive processing and working memory capacity of a person (Huettig & Janse, in press). Huettig and Janse employed the visual world paradigm to investigate predictive processing based on eye-movements made during listening to sentences. Several measures for working memory capacity were obtained from these participants and subsequently combined into one using principal component analysis. It turned out to significantly modulate predictive processing – individuals with higher working memory capacity predicted an upcoming referent earlier. This study presented sentences of the type "Look at the depicted object" where the definite article 'the' is marked for a grammatical gender in Dutch and this information can be used to figure out which of the four objects seen on the screen will be mentioned at the end of the sentence. As argued by the authors, working memory is especially relevant in this situation when the four objects are stored in memory and should be immediately accessed when something that helps to distinguish them appears in the input. In this setting, predictive processing concerns anticipation of a referent solely based on the grammatical information within a sentence. Arguably, differences in working memory should also be relevant in case of complex, discourse-based inferences, stretching across several sentences (with no need of linking with visual stimuli involved). Here, the capacity to store and manipulate information from previous discourse should be important, as any predictions about the upcoming items has to be based on the information given earlier. In our current study, we explored whether working memory capacity is indeed relevant for predictive processing.

There has also been an EEG study looking into individual differences in working memory capacity and predictive processing, but no effects of working memory were obtained (Otten

& Van Berkum, 2009). Otten and Van Berkum presented participants with two-sentence stories in which the first sentence set up a context and the second sentence contained a highly predictable word. Overall, the unexpected word elicited a negative deflection in ERPs in the time-window 200-600 ms. However, working memory capacity did not predict the size of this effect. The present study employed the same experimental design as the study by Otten and Van Berkum, but a different measure for working memory and a different type of analysis was conducted. Otten and Van Berkum (2009) used a reading span task (as described in Daneman & Carpenter, 1983) as a measure of working memory capacity which only requires memorizing a series of words and reporting them in the same order, so it may not reflect the ability to manipulate information in memory. They also divided their participants into two groups rather than analyzing the working memory capacity as a continuous variable, which could have resulted in significant reduction of important variance. We planned to analyze working memory capacity with regards to our data as a continuous variable, thus hoping to improve our ability to establish the role of working memory.

Processing speed

The second individual difference that we investigate is "processing speed" which we use to refer to the speed with which various processing tasks can be executed and information is retrieved by the brain (see Kail & Salthouse, 1994; Salthouse, 1996, 2000). The notion of processing speed was originally developed in the line of research on changes in cognitive performance associated with aging. There is no clear understanding of what exactly processing speed is from a cognitive or neurobiological perspective. It could reflect, for example, the speed with which neural signals are conducted along axons, or synchronization of neural impulses (Salthouse 2000). However, processing speed has been suggested to be generally different for different individuals regardless of their age, and differences in processing speed have been previously found to correlate with the performance in various cognitive tasks (e.g. Bull & Johnston, 1997; Caplan & Waters, 2003; Fry & Hale, 2000). In terms of language processing, it has been previously suggested that differences in processing speed may account for differences in sentence comprehension between younger and older adults (Peelle, Troiani, Wingfield, & Grossman, 2009) or, for example, play a role in language impairments (Leonard et al., 2007).

Processing speed should be relevant for predictive processing in language comprehension since the predictions in natural communication situations have to be formed quickly as the input comes rapidly (especially in spoken language input). Individuals that can process information faster could be faster in accessing the words' meanings from the long-term memory, making inferences, disregarding the irrelevant information and forming predictions. The study by Huettig and Janse (in press) mentioned above also looked into processing speed and indeed found that although its contribution is small, it is relevant and is separable from the WMC contribution. Here, we look into whether this would also be a significant predictor of EEG responses.

Inhibitory control

The final individual difference in cognitive capacities that we measured was inhibitory control. Inhibitory control refers to how well a person can suppress irrelevant, distracting information, and focus on the information relevant to the current task. Inhibitory control (or suppression ability) has been argued to be of relevance for language comprehension because we need to suppress the context-irrelevant information that is automatically retrieved and individuals have been found to significantly differ in this ability (e.g. Chwilla & Kolk, 2003; Gernsbacher & Faust, 1991; Gernsbacher, 1997). Word-level meanings that are retrieved during language comprehension can lead to other related meanings being retrieved (e.g. the *young* and *unmarried* meanings of *student*) that may or may not be relevant to the currently processed sentences. If irrelevant words are retrieved, they need to be suppressed in order not to distract from the currently relevant line of discourse based on which the predictions should be made. Thus, we expect that in the task of forming predictions based on discourse-level information, individuals with better inhibitory control abilities should show stronger predictions based on the discourse-level message.

To our knowledge, inhibitory control has not yet been directly investigated as a potential mediator of predictive processing. However, an EEG study that investigated a related question has been reported (Boudewyn, Long, & Swaab, 2012). The study by Boudewyn and colleagues looked at whether individual differences in cognitive control modulate the influence of lexical association on word recognition. Individuals were presented with sentences that contained strongly associated pairs of words (e.g. "In her haste she forgot apples and oranges") or the same sentences in which the second word in the pair is substituted by something unexpected (e.g. "In her haste she forgot apples and bread"). They found that individuals who were worse at inhibiting irrelevant information were less able to suppress the strongly learned associations – they anticipated the second word of the pair even though the association was not relevant in this particular context. The authors reason that perhaps individuals with poor cognitive control abilities are more affected by the immediate context, whereas those with better cognitive control abilities would be able to "keep their focus" on the more global, discourse situation model.

It should be noted, however, that another study from the same lab (Boudewyn, Long, & Swaab, 2013) looked at the effect of a global context using a similar design - the sentences from the previous study were presented as the final portion of a three-sentence passage, - and there they failed to obtain a significant modulation by inhibitory control. The authors suggest that this inconsistent result may have emerged due to a different strategy adopted by the participants of this study in their inhibitory control measure (they used the Stroop task) as evidenced by different results. One other explanation for inhibitory control not being a significant predictor in this specific setting could have been that the wellfounded context provided enough grounds to inhibit irrelevant semantic associations even for individuals with low inhibitory control, because these associations were easy to overwrite. In the case of our study, we are not looking at just inhibition of simple associations, but at the cases where the attention needs to be focused on the relevant line of discourse throughout the entire first

sentence in order to make the prediction. Thus, arguably, inhibition should be more important for predictions in our design.

Current study design

The current study aimed at investigating whether working memory capacity, processing speed and inhibitory control are relevant modulating factors for predictive processing. The design of our study was based on the design used by Otten and Van Berkum (2009)[1]. We recorded participant's EEG as they read two-sentence stories in which the second sentence contained either a highly expected noun preceded by a grammatical gender-marked determiner or an unexpected one but still consistent with the context. See *Table 1* for the examples of experimental stimuli. Since the items we are interested in should be predicted based on the information given in the previous sentence, we see it as discourse-level prediction.

Table 1. *Examples of experimental stimuli.*

Expected target noun and determiner	**Unexpected target noun and determiner**
Nadat hij uren naar het lege doek had gekeken voelde de schilder inspiratie opkomen. Hij greep naar **de** intensief gebruikte **kwast** en smeet de verf op het doek. *After hours of looking at the blank canvas, inspiration finally struck the painter.* *He reached for the$_{common}$ heavily used brush$_{common}$ and threw the paint on the canvas.*	Nadat hij uren naar het lege doek had gekeken voelde de schilder inspiratie opkomen. Hij greep naar **het** intensief gebruikte **penseel** en smeet de verf op het doek. *After hours of looking at the blank canvas, inspiration finally struck the painter.* *He reached for the$_{neuter}$ heavily used pencil$_{neuter}$ and threw the paint on the canvas.*
Het was een prachtige zonnige dag en Thomas en zijn vrienden wilden gaan picknicken. Ze gingen naar **het** grote aangename **park** om daar de middag door te brengen. *It was a beautiful sunny day and Thomas and his friends wanted to go on a picnic.* *They went to the$_{neuter}$ big pleasant park$_{neuter}$ to spend the afternoon there.*	Het was een prachtige zonnige dag en Thomas en zijn vrienden wilden gaan picknicken. Ze gingen naar **de** grote aangename **speeltuin** om daar de middag door te brengen. *It was a beautiful sunny day and Thomas and his friends wanted to go on a picnic.* *They went to the$_{common}$ big pleasant playground$_{common}$ to spend the afternoon there.*

[1] The original study also included a prime control condition which helped distinguish purely priming based effects and genuine prediction effects. We did not include this condition in our study because we decided to rely on the results of the original study showing that the observed effects in these sentences are not just priming effects, although there could potentially be a modulation of priming effects by inhibitory control that would be relevant for us.

In order to avoid the problem with two possible interpretations of an observed neural response as a prediction mismatch effect or integration difficulty (DeLong et al., 2005; Wicha, Moreno & Kutas 2004), we looked at the ERP effect already at the gender-marked determiner of the target noun instead of the noun itself. In Dutch, every noun has a fixed grammatical gender which is used in marking morphosyntactic agreement. Two genders are distinguished: common gender marked by the definite article *de* and neuter gender marked by the definite article *het* (thus, de kamer ("the room"), but *het kamer, and het huis ("the house"), but *de huis). It has been previously established (DeLong et al., 2005; Otten & Van Berkum, 2009; Martin et al. 2013) that it is not only the noun, but also its determiner that is anticipated by the comprehender[2] and the so-called N400 effect that is typically observed in evoked ERPs for unexpected items (Kutas & Federmeier, 2011; Kutas & Hillyard, 1984) can already be seen at the determiner. The study by Otten and Van Berkum did not find a typical N400 effect at an unexpected determiner, but a more anterior negative deflection and this is also what we expected to obtain in our study.

Assuming that if predictions are stronger or a participant is more committed to her predictions, the negative deflection in ERPs in response to the prediction-inconsistent/unexpected item (as opposed to prediction-consistent/expected item) would be larger, we used the size of this effect per participant as our dependent variable in the individual differences analysis. Alternatively, since we are averaging over all trials, a larger average effect size could be a result of a participant predicting in a case of more of the experimental items. In either case a stronger predictive ability should be reflected by larger differences in amplitudes per participant.

As our predictor variables, we collected individual scores for all participants in various tasks thought to measure the cognitive capacities of interest. In case of working memory and processing speed we collected the same measures as in the study by Huettig and Janse (in press), since we aimed at replicating their results with a different method and design. In addition, as a measure of inhibitory control, we used the so-called Flanker task. The description of each of these tasks along with the rationale behind choosing them is given in the Method section below.

We hypothesized that higher working memory capacity, faster processing speed and better inhibitory control should result in better predictive processing as would be evidenced by larger negative deflection upon encountering an unexpected item.

It should also be noted that we assume that these three cognitive capacities are separable and independently contribute to predictive processing ability. However, this does not need to be the case. For example, processing speed and WMC can be related – working memory capacity could depend on the speed of rehearsal (e.g. whether 5 or 10 items can be rehearsed in 500 ms.). On the other hand, they are unlikely to completely overlap as, for example, the

[2] Alternatively, the effect could be there, because upon encountering the determiner it becomes apparent that the prediction is not going to be fulfilled. The exact source of the effect is not important for us here, because in both cases it is a signature of the prediction mismatch before the predicted word itself appears.

speed with which an operation is performed may be slow regardless of availability of an item in memory (see Leonard et al. 2007 for a discussion). In this study we would like to assess the separable contribution of each of these cognitive capacities (the study by Huettig & Janse, for example, does find independent contributions of WMC and processing speed).

2. Method

Participants

Thirty-one native speakers of Dutch (10 male) from the participant panel of the Max Planck Institute for Psycholinguistics in Nijmegen, the Netherlands have been recruited to take part in this study. One participant was excluded due to not taking the experimental tasks seriously as evidenced by unwillingness to follow the instructions, extremely low scores and previous experience with this participant at the lab. Another participant was excluded due to low quality of the obtained EEG data that resulted in less than half of the experimental trials being valid. Thus, 29 participants were included in the final analyses. The mean age of these participants was 22.3 years (range 19-30, SD 2.8). All participants were right-handed, with normal or corrected to normal vision and had no history of language-related impairments, all self-reported. The participants were informed about the experimental procedures and were paid for participation according to the regulations of the local ethics committee.

Materials and design

The critical experimental stimuli were 112 mini-stories consisting of two sentences each. The first sentence set up the context and the second sentence contained the target determiner and noun. The prediction of the target word could only be made on the basis of the meaning of the first sentence. The second sentence up to the target determiner was not informative. The target determiner and the noun were always separated by 2 to 5 adjectives in order to ensure that the effects observed at the determiner cannot be attributed to processing of the target noun. Some of the stories were slightly modified versions of the materials used by Otten and Van Berkum (2009) and the rest were created from scratch.

For each story, we created a prediction-consistent (expected) version, which contained a highly predictable noun and a corresponding determiner, and a prediction-inconsistent version, which contained an unpredictable (unexpected), but plausible and coherent noun of the other gender and a corresponding determiner (see *Table 1* for examples). The consistent and inconsistent versions of the stories were identical except for the critical region in the second sentence, which contained the target determiner, intervening adjectives and the target noun. Fifty-eight experimental sentences contained a highly predictable common gender noun and determiner and 54 contained a highly predictable neuter gender noun. All sentences were judged as plausible by two native speakers of Dutch. The full list of stimuli can be found in the Appendix.

In order to establish the predictability of the target nouns in our stimuli, a cloze task was administered to 15 native Dutch speakers from the same population and of the same age range (mean age: 22.3, SD: 3.7, range 19-34; 4 female, 11 male) in the form of an online questionnaire. The participants were also paid for their time. They saw the first sentence of each story as well as the second sentence cropped at the position of the determiner (i.e. without the determiner) and were asked to come up with a plausible continuation. Only the stories with highly predictable target nouns were selected for this experiment. In our set of the experimental stimuli, the mean cloze value (the proportion of participants that suggests this continuation) of the target noun in the consistent condition was 0.79 (SD 0.11; range from 0.60 to 1). The mean cloze value of the target words in the inconsistent condition was 0.01 (SD 0.04; range from 0 to 0.13).

Two lists were created, each containing one version of all stories. Half of the stories in a list were presented in the expected noun and determiner version and the other half of the sentences was presented in the unexpected version. The second list contained the other versions of these sentences. Besides our experimental stimuli, during the experiment each participant read 9 additional stories of similar structure and also with consistent or inconsistent versions for the purposes of another study. These sentences were not included in the analysis.

Procedure

At the start of the experimental session the participants were given information about experimental procedures without revealing the aim of the study and signed a consent form according to the regulations of Max Planck Institute for Psycholinguistics, where the data collection took place. After that, an EEG cap was set up. The main reading task with the experimental stimuli was administered first. We then administered three working memory tasks and two processing speed tasks fully repeating the tasks reported in Huettig and Janse (in press). However, subsequently we could not analyze our data by deriving a single score for working memory and a single score for processing speed because of the low total number of participants and low correlations between these tasks. For this reason, only the tasks that we decided to include in our final analysis are reported here. This will be further discussed in the Discussion section below. The flanker task was the only task that was administered for testing inhibitory control. Several more short tasks that are also not reported here were administered for the purposes of another study. All behavioral tasks were administered after the participants took the EEG cap off. During the experimental session, the participants were comfortably seated in a sound-isolated room while the experimenter was outside. At the end, participants received a written debriefing about the experimental design and goals. The whole session took 2 to 2.5 hours.

The experimental software scripts and scoring for the working memory and processing speed measures were the same as used by Huettig and Janse (in press). The lab used for data collection in this study was, however, different. The description of the tasks can be found in the original paper, but I will also describe them here in a little more detail for clarity. All tasks were run using Presentation software (Neurobehavioral Systems, www.neurobs.com)

except for the digit symbol substitution which was done on paper. The order of tasks was the same as the order in which they are presented here. In all cases except for the digit symbol substitution, the participants were given written instructions and the experimenter was present in the room for clarification questions and during the practice trials.

Main task

In the main task, during which EEG measurements were taken, the participants were asked to read the two-sentence stories (112 stories relevant for this study plus 9 additional stories for another study), understand them and sometimes answer questions about them. The comprehension questions were simple yes-no questions and were used in order to make the task more interactive and ensure participants' attention. There were comprehension questions after 25% of the trials (30 questions in total).

Each trial started with a fixation cross that remained on the screen for 2000 ms, followed by a blank screen for 350 ms. The first sentence was presented as a whole on the screen and the participants pressed a key in order to proceed when they were ready. This was followed by another fixation cross for 2000 ms and a blank screen for 350 ms. The second sentence was then presented word by word in the center of the screen. The second sentence could be followed by a comprehension question which participants answered using a button box. For presenting the second sentence containing the target words, we used the so-called Variable Serial Presentation procedure in analogy to Otten and Van Berkum studies (Otten & Van Berkum, 2007, 2009). In this procedure, the duration of presentation of each word depends on its length, which is supposed to make reading word by word more natural and faster. In our study, each word except for the critical region was presented for 187 ms plus the number of letters in the word multiplied by 30. For words that were 10 letters long or longer, the presentation time was fixed at 457 ms. The last word of the sentence remained on the screen for an additional 293 ms for sentence wrap-up effects. The words in the critical region (starting from the target determiner and up to and including the target noun) were presented at a fixed presentation rate of 358 ms. This number was determined based on the average length of a word in the critical region, which in our case was 5.7 letters. The interstimulus interval during word presentation was set at 400 ms. It should be noted that the presentation and interstimulus durations in this study were longer than in original Otten and Van Berkum design for external reasons[3].

In order to avoid muscular movement artefacts, participants were asked not to blink during the second sentence presentation (thus they could blink during the first sentence presentation). No information was given on which part of the task we are most interested in. We decided to present the first sentence as a whole since the stories were too long to be presented word by word, both in terms of the time it would take and the comfort of the participants (it would be problematic for them not to blink for such a long time). This way of

[3] The data reported in this paper were recorded as control data in another study and for that study the inter-stimulus interval and word presentation time had to be longer than the ones we would opt for otherwise. I return to the discussion of the potential issues with the timing of presentation in the *Discussion* section.

stimulus presentation has been successfully used before and is not considered to seriously affect processing (e.g. Foucart et al., 2014; Wlotko & Federmeier, 2015).

The sentences were presented in black font (Arial, 21 pt.) against a light gray background. The order of presentation of the trials was random and differed for each participant. The trials were divided into four blocks of equal length with three breaks for the participants to rest. Each block lasted for approximately 10-15 minutes depending on the reading speed of the participant and the total duration of the reading task was around 45 minutes.

Inhibitory control: Flanker task

As a measure of inhibitory control, we used the so-called Flanker task (Eriksen & Eriksen, 1974). In this task, the participants are presented with a string of 5 arrows in the middle of the screen and are asked to press a button corresponding to the direction of the middle arrow ("left" or "right") while ignoring the directions of the two arrows on each side. The four side arrows could point in either the same direction as the middle one (congruent trials), a different direction from the middle one (incongruent trials) or were substituted with just horizontal lines (neutral trials) (3 conditions in total). The participants were asked to press a button as soon as possible. The task indexes inhibitory control since, in the incongruent trials, individuals have to inhibit the urge to press a button based on the automatically-priming four side arrows to make a decision based on only one arrow.

Our participants were first presented with 6 practice trials and then with 102 experimental trials divided into 2 blocks. There were 34 experimental trials per condition. Each trial started with a beep sound and a fixation cross that remained on the screen for 300 ms. It was followed by a blank page that remained on the screen for a randomly chosen amount of time - 250, 750, 1250 or 1600 ms. The pattern was then presented in white against black background. As soon as the participant pressed a button or if no response was given within 1500 ms, the pattern disappeared and the next trial started.

Two participants were excluded from the analyses since they only gave a few or no correct responses in the incongruent condition. The flanker scores were calculated using the reaction times in correct trials only. The mean accuracy rate was .91 overall. As expected, the overall mean reaction time in incongruent condition was higher than the reaction time in congruent condition – 563 and 467 ms. respectively; the mean reaction time in the neutral condition was 453 ms. The flanker effect for each participant was obtained by first log-transforming the average reaction times for incongruent and neutral conditions and then obtaining a ratio of the log RT in the incongruent condition and the log RT in the neutral condition. Larger ratios here indicated poorer performance in the task or in other words worse inhibitory control. The mean flanker score was 1.034 (SD: 0.013; range 1.013-1.062).*Processing speed: Digit symbol substitution*

This was a pen and paper task in which participants saw digits from 1 to 9 each paired with a symbol. This served as a key for substituting rows of numbers for their corresponding symbols. The participants had 90 seconds in order to copy as many symbols as possible. The task is originally part of the Wechsler Adult Intelligence Test and has been repeatedly used as

a measure of processing speed (Caplan & Waters, 2003; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Hoyer, Stawski, Wasylyshyn, & Verhaeghen, 2004; Salthouse, 1996). This task is meant to put minimal demands on the maintenance of information or inhibition, thus it is not supposed to reflect working memory or inhibitory control, but purely the speed with which the information in the processing system can be transferred (for each given digit, check the symbol on the top of the page, copy this symbol in the corresponding box).

The maximum number of symbols that could be substituted was 113. The score in this test is calculated by dividing the number of copied symbols by 90 seconds. This way we obtained a substitution time per symbol. Higher scores in this task indicate poorer performance or, in other words, lower processing speed. The mean score for our set of participants was 1.45 (SD 0.43; range 0.95 - 2.86).

Working memory: Backward digit span

As an index of working memory capacity, the backward version of the common digit span task was administered. In each trial, a sequence of digits was presented in the center of the screen. The participants' task was to memorize the digits and report them back in the reverse order (e.g. "417" should be reported back as "714"). The task is originally part of the Wechsler Adult Intelligence Test. The task is thought to assess the ability to simultaneously store, process and manipulate information in verbal working memory, since the digits have to be rehearsed in memory while the new ones are shown and their order has to be reversed at the end.

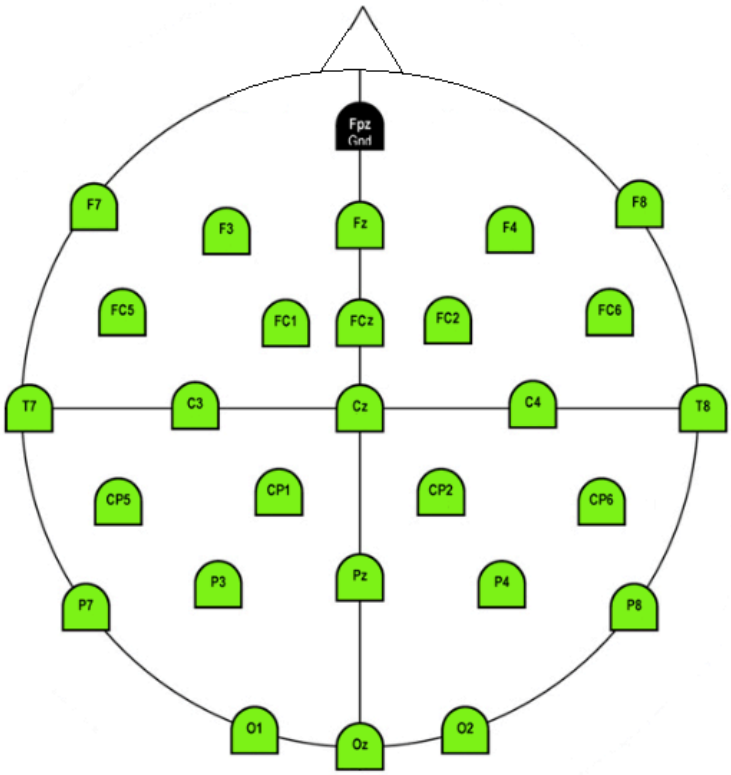
The digits were presented in large font (Arial, size 14), in white color against black background. Each digit was presented for one second followed by a second-long blank screen before the next digit appeared. After the last digit of the sequence, the participant was prompted to give an answer. A computer keyboard was used to enter the answers. Participants were presented with two three-digit trials for practice. After that, they saw sequences of two to eight digits long, each sequence length repeated twice. This way there were 14 trials in total. The longer sequences were presented regardless of whether the participants were able to correctly recall the previous shorter sequences. It is important to note that all participants saw the same digits in all trials and in the same order. For each participant, we took the number of correctly recalled sequences in total as their score in this task. After the evaluation of the results, it became apparent that 2 participants did not understand the task and reported the sequences without reversing them. The scores for these participants were not included in the analysis. The mean score for our participants was 9.4 out of 14 (SD 2.7; range 4-13). The higher scores in this task mean higher working memorycapacity.

EEG recording and analysis

The EEG signal was recorded continuously from 27 active scalp electrodes mounted in an elastic cap (ActiCAP), placed according to the 10-20 convention (the location of the scalp

electrodes is depicted in *Figure 1*). In addition to the scalp electrodes, four electrooculogram (EOG) electrodes were used to detect eye-movements and blinks - to the left of the left eye, above and below the left eye and to the right of the right eye. Finally, two reference electrodes were placed on both mastoid bones. The signal was amplified using BrainAmp DC and recorded using BrainVision Recorder (Brain Products GmbH, www.brainproducts.com). All electrode impedances were kept below 5 kΩ. The recording was done at a sampling rate of 500 Hz, with a time constant of 10 s (0.016 Hz). The signal was online referenced to the left mastoid and online filtered with a low pass filter at 150 Hz.

Figure 1. *Locations of 27 scalp electrodes*.



For offline data processing, we used BrainVision Analyzer 2 (Brain Products GmbH, www.brainproducts.com). The recordings were re-referenced to the average of the left and right mastoids and filtered with a bandpass zero phase shift filter with high cutoff at 35 Hz. The blinks were removed from the recordings using ocular correction as described in Gratton and colleagues (Gratton, Coles, & Donchin, 1983) and implemented in BrainVision Analyzer 2. The data were then segmented into epochs that included 100 ms prior to the critical stimuli (the determiner), and 1000 ms after the critical stimuli onset (the presentation time of the determiner was 358 ms and there was a blank screen for 400 ms before the appearance of the next word, so the time interval in which we could look for effects without including the next word was up to 758 ms after stimulus onset). The epochs were baseline-corrected for 100 ms

prior to stimuli presentation. Finally, the epochs with the amplitudes below -75 V and above +75 V were removed. This way, 6.7% of the total number of epochs were rejected in the expected condition and 6.9% in the unexpected condition (6.8% of epochs rejected in total for both conditions). For every participant we ended up with above 39 total epochs per condition (39 was the lowest number - on average we had 51 good epochs per condition per participant).

3. Results

In order to ensure that participants paid attention during the reading task, we evaluated their responses to the comprehension questions. All 29 participants gave correct responses in more than 80% of the questions (mean 88%, SD 3.9) and thus all of them were included in further analyses.

For all statistical tests reported below, we used R software (R Core Team, 2015).

Overall expectedness effect

Before turning to individual differences analysis, we checked our data for the presence of a global effect – whether the unexpected determiner has elicited a more negative deflection in ERPs compared to expected determiners across all participants. *Figure 3* shows ERPs elicited by expected and unexpected determiners on 6 electrodes (2 frontal, 2 central, 2 parietal) averaged over all participants. Visual inspection of ERPs suggests that there is only a minor increase in negativity for the unexpected condition in an N400-like time window, but more so over posterior electrodes. The distribution of the effect over the scalp (see *Figure 2*), also suggests that there is more negativity for the unexpected condition in posterior regions, especially in 250-300 ms and 350-400 ms time-windows.

Since we used the design and materials similar to Otten and Van Berkum (2009) study, we expected to replicate the overall effects that they obtained. Following their analysis, we looked at the time window 200-600 ms after determiner onset. To account for possible differences between different electrode sites, we used Anteriority (anterior vs. posterior electrodes) and Hemisphere (left and right) as spatial factors in our analysis. The four resulting regions were as follows: Left Anterior (electrodes F7, F3, FC5, FC1, C3, T7), Right Anterior (F4, F8, FC2, FC6, C4, T8), Left Posterior (CP5, CP1, P7, P3, O1) and Right Posterior (CP2, CP6, P4, P8, O2) (see *Figure 1* for the locations of these electrodes on the scalp). We performed repeated measures ANOVA on mean amplitudes as the dependent variable with Condition, Anteriority and Hemisphere as within-participant factors. This analysis produced a significant main effect of Anteriority [$F(1,28)=42.51$, $p<.001$], a main effect of Hemisphere [$F(1,28)=12.32$, $p<.01$] and Anteriority by Hemisphere interaction [$F(1,28)=44.9$, $p<.001$]. In addition, we obtained not significant at the probability level .05, but trending to significance a main effect of Condition [$F(1,28)=3.66$, $p=.066$] and Anteriority by Condition interaction [$F(1,28)=3.5$, $p=.072$]. There was no Condition by Hemisphere interaction [$F(1,28)=1.45$, $p=.239$]. The topography of the effect depicted on the

topomaps suggests that the posterior electrodes produce the effect. In order to verify this, we then conducted separate ANOVAs for anterior and posterior electrodes. As we expected, the effect was significant over the posterior electrodes [$F(1,28)=5.64$, $p<.025$], but not over the anterior electrodes [$F(1,28)=0.92$, $p<.347$].

Thus, in our study, an unexpected determiner also produced an overall negative deflection in the ERPs in comparison with an expected one in the time-window 200-600 ms, as was the case in Otten and Van Berkum (2009). However, the effect obtained by us has a different topography – it is clearly posterior, whereas the effect in the original study by Otten and Van Berkum was distributed over the whole scalp and had the maximum in anterior regions. The possible reasons for this difference will be discussed in the *Discussion* section below.

Figure 2. *The topography of the observed effect over time. The average amplitude difference between expected and unexpected conditions for all participants is depicted.*

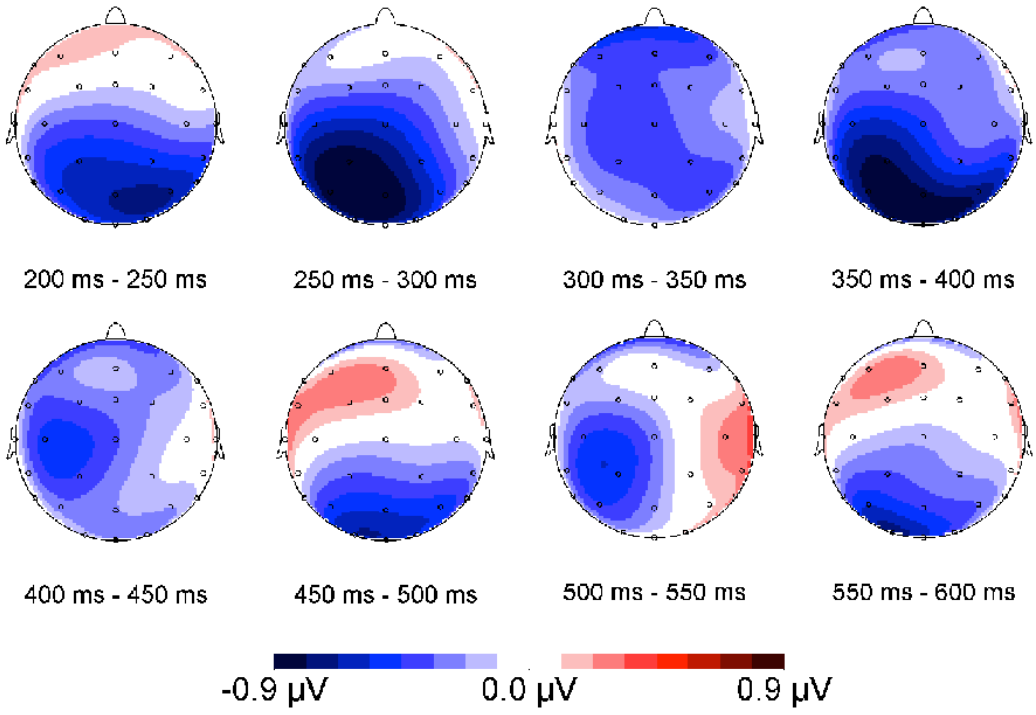
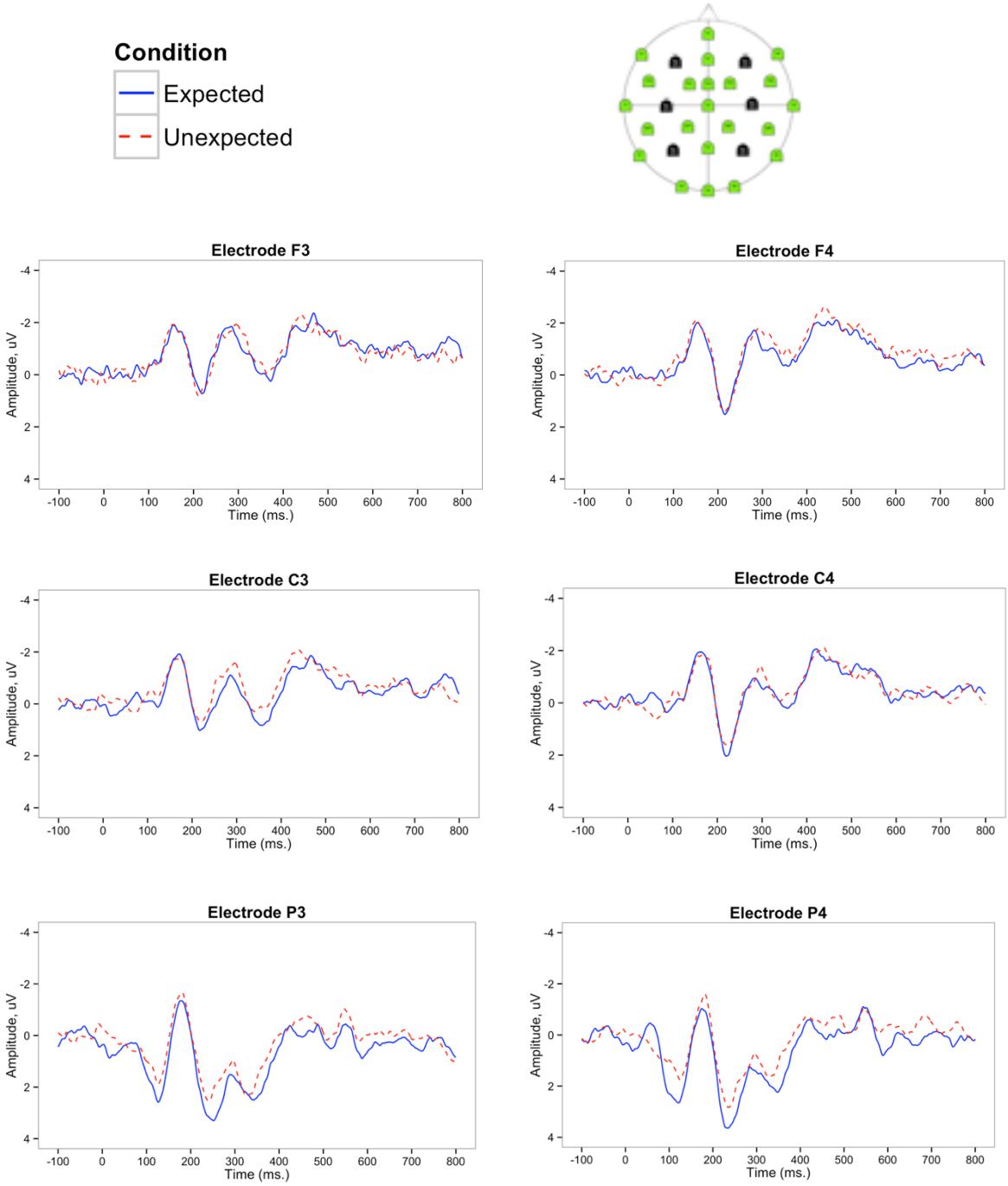


Figure 3. *ERPs for the determiner in two conditions. Negativity is plotted upwards.*

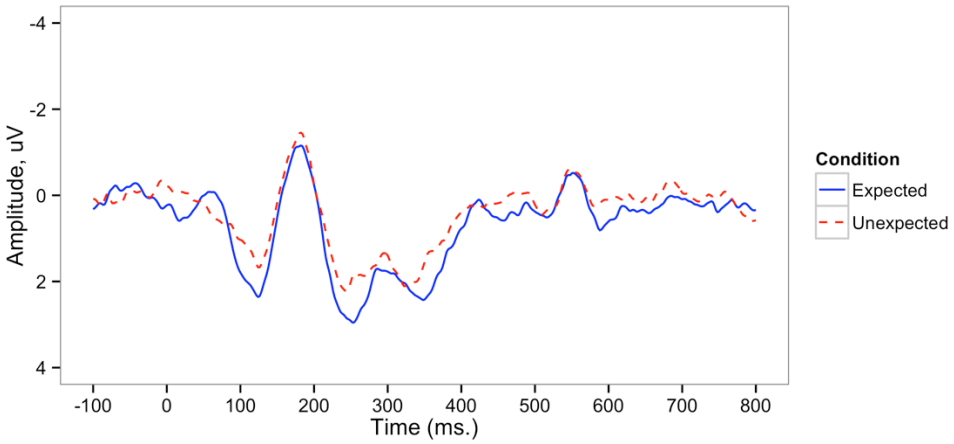


Individual differences

Next, we explored our data for the presence of a modulation of the effect by individual differences in the cognitive capacities as we hypothesized. The overall analysis showed that our effect is maximal over posterior electrodes and such topography is also consistent with the topography of typical predictability N400 effects (Swaab, Ledoux, Camblin, & Boudewyn, 2011). For these reasons, for the individual differences analysis we decided to

take the signal recorded only over posterior electrodes. Specifically, we included Pz, P3, P4, P7, P8. *Figure 4* depicts the ERPs recorded over this subset of electrodes for all participants.

Figure 4. *ERPs for the determiner in two conditions over the selected posterior electrodes (Pz, P3, P4, P7, P8).*



We conducted a multiple regression analysis with the difference in the mean amplitudes over these electrodes in the same 200-600 ms time-window between expected and unexpected conditions as the predicted variable and individual measures as predictors. Inhibitory control, working memory and processing speed were treated as continuous variables. These variables did not correlate with each other (see *Table 2*).

Table 2. Correlations between flanker task, symbol substitution and digit span scores.

	Flanker task	**Symbol substitution**	**Digit span**
Flanker task	1.0		
Symbol substitution	0.26	1.0	
Digit span	-0.07	0.09	1.0

It should be noted that performing a regression analysis on individual scores in ERP data is not a common practice in psycholinguistic research due to the poor signal-to-noise ratio. The usual low number of experimental items per condition means that the amplitudes for different items are commonly averaged per participant and then mean amplitudes of all participants are also combined to obtain reliable results. However, in our case we have 56 items per condition which is more than is usually the case in this kind of study. This way, in exchange for having a more noisy signal, we are advantaged in that we can include all variables in the same regression model which would not be possible with the traditional ANOVA approach and we

do not need to lose variance in our continuous variables by diving them into only few levels. Regression analyses on individual ERPs have already been successfully applied before (e.g. Boudewyn et al., 2012, 2013; Dambacher, Kliegl, Hofmann, & Jacobs, 2006; Laszlo & Federmeier, 2009), although with a higher number of participants.

The results of the linear regression analysis (performed using the lm() function in R) are reported in *Table 3*. This analysis revealed no significant effects (r^2=0.05; p=0.98).

Table 3. *Results of the multiple regression analysis on the mean ERP effect size in posterior region (electrodes Pz, P3, P4, P7 and P8). Unstandardized coefficients (b), standard error and probability levels (p) are reported.*

Predictor	**b**	**Std.Error**	**p**
(Intercept)	-2.30	14.9	
Flanker score	1.95	14.24	0.90
Digit span	-0.02	0.06	0.80
Symbol substitution	0.12	0.45	0.80

4. Discussion

The study reported here had a goal of testing whether individual differences in cognitive capacities traditionally looked at in psycholinguistic and cognitive psychological research modulate predictive processing during language comprehension. We opted for the discourse-based prediction where a word has to be predicted based on the context information given in the previous sentence. The idea was to look into predictive processing by investigating expectedness effects on ERPs at a gender marked determiner of a highly expected and an unexpected noun. We obtained an overall effect of prediction, although with a different topography than expected, but failed to obtain modulations by individual cognitive capacities as we hypothesized. In this section, I will discuss some of the possible explanations for our overall findings diverging from the original finding in the study of Otten and Van Berkum (2009), as well as the failure to find modulation of the effect by individual differences, which have been reported previously for different designs and materials (e.g. Boudewyn et al. 2012, 2013; Huettig & Janse, in press).

Our study was based on the design of, and used almost the same materials as Otten and Van Berkum (2009), but the effect that we obtained is different from their original finding. The negativity we recorded in processing an unexpected item was only posterior, whereas in the original study it was present over the whole scalp with a maximum over anterior electrodes. There are several differences in the way the studies were conducted that could have caused different results. First, in our study we presented words with 400 ms between them, whereas

the original interstimulus interval was just 106 ms. It has been recently demonstrated that when the stimuli are presented with a too-small interstimulus interval (too quickly), the prediction effect can disappear (Wlotko & Federmeier, 2015) - thus, different timing of the presentation *can* influence predictive processing effects. Another potential explanation for obtaining different results is the different cloze probabilities of the target words included. In the original study, the mean cloze probability in the expected condition was 0.74 (SD 0.14). It was collected by cropping the second sentence in the stimuli at the position of the determiner and adding an indefinite determiner instead (Otten 2008) which constrained the item that the participants could come up with - only a noun can come after an indefinite determiner (and in Dutch an indefinite determiner does not differ depending on the grammatical gender of the noun it is modifying). In our case the mean cloze probability was 0.79 (SD 0.11). However, we did not add this indefinite determiner and thus the participants had more choice in the grammatical class of the word that they chose as a continuation. As a result, in many cases they did not use a noun at all. Thus, our cloze probabilities are more conservative. As was already mentioned, our finding posterior maximum is more typical for predictability N400 effects (Swaab et al. 2011). The high cloze probabilities that we had are also more typical for studies on predictive language processing, so our result could be more conforming to those for this reason. Because of the anterior maximum of the obtainedeffects, Otten and Van Berkum could not classify their finding as an N400 effect. The effect that we obtained, however, can be classified as such and thus could be argued to be a result of the same qualitative process as in case of other type of stimuli that elicited the N400 effect (see Kutas & Federmeier 2011 for a review).

The absence of modulation of the predictability effect by the individual differences could either mean that there genuinely is no such modulation or that our chosen type of analysis or experimental setting failed to capture it. There are several things that could go wrong with regards to each of these. In terms of methodology, the biggest drawback of the current study is the low total number of participants for conducting a multiple regression analysis on individual ERP effects. As it has already been mentioned, the high level of noise in EEG measurements makes averaging over many trials necessary and in case of individual differences analyses it also requires a high number of participants. For example, the study by Boudewyn and colleagues that successfully employed this method (Boudewyn et al., 2012) had over 50 participants. The study by Lazslo and Federmeir (2009) had 120 participants. On the other hand, such analysis was also successfully applied in another study by Boudewyn and colleagues (Boudewyn et al., 2013) with only 26 participants. Another methodological reason for not obtaining a modulation by individual cognitive capacities could be that we chose a wide time-window for the individual analysis based on the results of Otten & Van Berkum, 200-600 ms However, such a wide effect window could be the result of some participants showing an effect earlier and some later. An alternative way of exploring our hypotheses would be visually inspecting ERPs for different groups of participants based on their performance in our tasks and determining where the group differences may lay. Thus, besides the size of the effect, we could also potentially explore different latencies of the peak. This is something we are planning to do in the future.

In terms of the experimental settings, perhaps the participants in our study had too much time to process the words for the effects of processing speed or inhibitory control to show up. With 400 ms pauses between words, the rate of presentation in our study was at a comfortable reading pace and was arguably even slower than in natural speech. Having enough time could have allowed for slow processing of all given information and inhibition of irrelevant information for all participants.

Turning to the discussion of why there may genuinely not be a modulation of predictive processing by our predicted variables, the effects of working memory capacity were previously obtained using eye-tracking with a visual world paradigm (Huettig & Janse, 2015) where the participants see several objects on the screen and the ability to store them in working memory for immediate integration with the incoming input may be especially relevant there, but not be of much relevance for processing discourse information. We have reasoned that individuals need to store the information about the already given discourse model in working memory in order to predict and this consumed working memory resources. However, this does not have to be the case. For example, the memory-based text processing framework (Gerrig & O'Brien 2005, Myers & O'Brien 1998) assumes that we do not store the information relevant for the currently processed text in working memory, but we rather store cues to long-term memory which allow for rapid automatic access of these relevant representations. In this framework, rather than being actively retrieved, the information related to the incoming words or phrases becomes available automatically and inferences are also made with no or little cost. Thus, according to this framework, inferences needed for predictive processing would not burden working memory resources.

Our finding of the lack of modulation of the size of the predictability effect by inhibitory control is consistent with the finding by Boudewyn and colleagues (Boudewyn et al. 2013) discussed above. In their study as well, when a strong semantic association was violated after a context in which it was consistent has been established, inhibitory control stopped being relevant for the efficiency of its processing. A possible explanation is that inhibitory control capacity plays a role in cases when there is not much information provided in the previous discourse on the grounds of which relevant information can be filtered out, but if sufficient information is provided by the previous context, everyone can suppress the obviously irrelevant associations.

Extending our original ideas, although individual differences did not modulate the size of the effect at the position of the unexpected determiner in our study, there can still be a modulation at other points in experimental sentences. For example, so far the ERP effects on the predicted noun itself were not mentioned in this paper since we had no clear predictions regarding them, but it could be something else to be explored. In the sentences that our participants read, the predicted determiner and the noun had 2-5 adjectives intervening. In the unexpected condition, the gender information at the determiner already signals that the upcoming noun is not going to be what the comprehenders expect. One possibility is that only some of the participants will be able to adjust their predictions based on this information by the time they encounter the noun and how much time they need for that or if they are able to

do it at all could also be modulated by the individual differences. This option will be explored by us in further analyses.

Finally, a point regarding the way this study was conducted needs to be made. We collected measures in three tasks thought to measure working memory and two tasks thought to measure processing speed planning to obtain a single score for each of these using Principal Component Analysis (PCA), thus fully repeating the method used by Huettig and Janse, but did not do so in the end. In addition to the tasks reported above, we also collected scores for a non-word repetition task, the Corsi block task for working memory, and a letter detection task for processing speed (all using the same scripts and procedures as described in the Huettig and Janse study). However, using PCA to derive one score was not possible for us due to low correlations between the scores for our participants. All our correlations were below .20, whereas in the original study they were 0.30-0.60. In order for the PCA to give meaningful values, the scores have to correlate sufficiently. The reason for this difference between the correlations is likely to be the low number of participants (only 29 as opposed to over 100 in the original study), and possibly homogeneity of our population sample. Potentially extending this study in future by collecting data from more participants may result in a higher correlation between the scores enabling PCA. For our analysis, we had to select which of the administered tasks to use for the individual differences. As the best working memory measure, we decided to choose the digit span task as this task is the most commonly used one and can be argued to capture both storage and manipulation of information in working memory at the same time. In addition, spatial working memory as reflected by the Corsi block test should not be as relevant for our stimuli where no pictures were shown and the nonword repetition task would only index storage of information and previously it has been mainly used for other purposes (e.g. for testing language development in children as in Gathercole et al. 1994), so they were not fitted for our study as much. The symbol substitution task and letter detection were both suggested in the original set of tasks by proponents of processing speed (Salthouse, 1996), but we decided to choose the symbol substitution as it has been more often used since.

In summary, no definite conclusions regarding the influence of individual cognitive capacities on predictive processing can be made on the basis of the present study. Our findings do not support the hypotheses put forward. If predictive processing is genuinely modulated by working memory capacity, inhibitory control, and processing speed, different experimental settings as well as a different approach to data analysis could reveal it in future studies.

References

Altmann, G. T. M., & Mirković, J. (2009). Incrementality and Prediction in Human Sentence Processing. *Cognitive Science*, *33*(4), 583–609.

Baddeley, A. (2003). Working memory: looking back and looking forward. *Nature Reviews Neuroscience*, *4*(10), 829–839.

Bornkessel, I. D., Fiebach, C. J., & Friederici, A. D. (2004). On the cost of syntactic ambiguity in human language comprehension: An individual differences approach. *Cognitive Brain Research, 21*(1), 11–21.

Borovsky, A., Elman, J. L., & Fernald, A. (2012). Knowing a lot for one's age: Vocabulary skill and not age is associated with anticipatory incremental sentence interpretation in children and adults. *Journal of Experimental Child Psychology, 112*(4), 417–36.

Boudewyn, M. A., Long, D. L., & Swaab, T. Y. (2012). Cognitive control influences the use of meaning relations during spoken sentence comprehension. *Neuropsychologia, 50*(11), 2659–2668.

Boudewyn, M. A., Long, D. L., & Swaab, T. Y. (2013). Effects of working memory span on processing of lexical associations and congruence in spoken discourse. *Frontiers in Psychology, 4*, 60.

Bull, R., & Johnston, R. S. (1997). Children's arithmetical difficulties: Contributions from processing speed, item identification, and short-term memory. *Journal of Experimental Child Psychology, 65*(1), 1–24.

Calvo, M. G. (2001). Working memory and inferences: Evidence from eye fixations during reading. *Memory, 9*(4-6), 365–381.

Caplan, D., & Waters, G. (2003). The relationship between age, processing speed, working memory capacity, and language comprehension. *Memory, 13*(3-4), 403–413.

Chwilla, D. J., & Kolk, H. H. (2003). Event-related potential and reaction time evidence for inhibition between alternative meanings of ambiguous words. *Brain and Language, 86*(2), 167–192.

Clark, A. (2013). Whatever next? Predictive brains, situated agents, and the future of cognitive science. *The Behavioral and Brain Sciences, 36*(3), 181–204.

Conway, A. R., Cowan, N., Bunting, M. F., Therriault, D. J., & Minkoff, S. R. (2002). A latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence, 30*(2), 163–183.

Dambacher, M., Kliegl, R., Hofmann, M., & Jacobs, A. M. (2006). Frequency and predictability effects on event-related potentials during reading. *Brain Research, 1084*(1), 89–103.

Daneman, M., & Carpenter, P. A. (1983). Individual differences in integrating information between and within sentences. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*(4), 561-584.

Dell, G. S., & Chang, F. (2014). The P-chain: Relating sentence production and its disorders to comprehension and acquisition. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369*(1634), 20120394.

DeLong, K. A., Urbach, T. P., & Kutas, M. (2005). Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. *Nature Neuroscience, 8*(8), 1117–21.

Dikker, S., Rabagliati, H., Farmer, T. A., & Pylkkänen, L. (2010). Early occipital sensitivity to syntactic category is based on form typicality. *Psychological Science, 21*(5), 629–34.

Dikker, S., Rabagliati, H., & Pylkkänen, L. (2009). Sensitivity to syntax in visual cortex. *Cognition, 110*(3), 293–321.

Ericsson, K. A., & Delaney, P. F. (1999). Long-term working memory as an alternative to capacity models of working memory in everyday skilled performance. In A. Miyake & P. Shah, *Models of working memory: Mechanisms of active maintenance and executive control*, 257-297. Cambridge, UK: Cambridge University Press.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological review, 102*(2), 211-245.

Eriksen, B., & Eriksen, C. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*(1), 143-149.

Estevez, A., & Calvo, M. G. (2000). Working memory capacity and time course of predictive inferences. *Memory, 8*(1), 51–61.

Federmeier, K. D., & Kutas, M. (1999). A Rose by Any Other Name: Long-Term Memory Structure and Sentence Processing. *Journal of Memory and Language, 41*(4), 469–495.

Federmeier, K. D., Kutas, M., & Schul, R. (2010). Age-related and individual differences in the use of prediction during language comprehension. *Brain and Language, 115*(3), 149–61.

Foucart, A., Martin, C. D., Moreno, E. M., & Costa, A. (2014). Can bilinguals see it coming? Word anticipation in L2 sentence reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*(4), 1–9.

Fry, A. F., & Hale, S. (2000). Relationships among processing speed, working memory, and fluid intelligence in children. *Biological Psychology, 54*(1), 1–34.

Gathercole, S. E., & Baddeley, A. D. (2014). *Working memory and language*. Psychology Press.

Gernsbacher, M. A. (1997). Two decades of structure building. *Discourse Processes, 23*(3), 265–304.

Gernsbacher, M. A., & Faust, M. E. (1991). The mechanism of suppression: a component of general comprehension skill. Journal of *Experimental Psychology: Learning, Memory, and Cognition, 17*(2), 245-262.

Gerrig, R. J., & O'Brien, E.J. (2005). The scope of memory-based processing. *Discourse Processes*, 39(2-3), 225-242.

Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology, 55*(4), 468–484.

Hoyer, W. J., Stawski, R. S., Wasylyshyn, C., & Verhaeghen, P. (2004). Adult age and digit symbol substitution performance: a meta-analysis. *Psychology and Aging, 19*(1), 211-214.

Huettig, F. (in press). Four central questions about prediction in language processing. *Brain Research*. doi:10.1016/j.brainres.2015.02.014. Retrieved from: http://pubman.mpdl.mpg.de/pubman/faces/viewItemOverviewPage.jsp?itemId=escidoc:2087802:5

Huettig, F., & Janse, E. (in press). Individual differences in working memory and processing speed predict anticipatory spoken language processing in the visual world. *Language, Cognition and Neuroscience*. Retrieved from: http://pubman.mpdl.mpg.de/pubman/faces/viewItemOverviewPage.jsp?itemId=escidoc:2148644

Jaeger, T. F., & Snider, N. E. (2013). Alignment as a consequence of expectation adaptation: Syntactic priming is affected by the prime's prediction error given both prior and recent experience. *Cognition, 127*(1), 57–83.

Janse, E., & Jesse, A. (2014). Working memory affects older adults' use of context in spoken-word recognition. *Quarterly Journal of Experimental Psychology, 67*(9), 1842–62.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: individual differences in working memory. *Psychological Review, 99*(1), 122-149.

Just, M. A., Carpenter, P. A., & Keller, T. A. (1996). The capacity theory of comprehension: new frontiers of evidence and arguments. *Psychological Review, 103* (4), 773-780.

Kaan, E. (2014). Predictive sentence processing in L2 and L1: What is different? Linguistic *Approaches to Bilingualism, 4*(2), 257–282.

Kail, R., & Salthouse, T. A. (1994). Processing speed as a mental capacity. *Acta Psychologica, 86*(2), 199–225.

Kim, A. E., & Gilley, P. M. (2013). Neural mechanisms of rapid sensitivity to syntactic anomaly. *Frontiers in Psychology, 4*, 45.

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event related brain potential (ERP). *Annual Review of Psychology, 62*, 621.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature, 307*, 161-163.

Laszlo, S., & Federmeier, K. D. (2009). A Beautiful Day in the Neighborhood: An Event-Related Potential Study of Lexical Relationships and Prediction in Context. *Journal of Memory and Language, 61*(3), 326–338.

Lau, E., Stroud, C., Plesch, S., & Phillips, C. (2006). The role of structural prediction in rapid syntactic analysis. *Brain and Language, 98*(1), 74–88.

Leonard, L. B., Weismer, S. E., Miller, C. A., Francis, D. J., Tomblin, J. B., & Kail, R. V. (2007). Speed of processing, working memory, and language impairment in children. J*ournal of Speech, Language, and Hearing Research, 50*(2), 408–428.

MacDonald, M. C., & Christiansen, M. H. (2002). Reassessing working memory: comment on Just and Carpenter (1992) and Waters and Caplan (1996). *Psychological Review, 109*(1), 35-54.

Mani, N., & Huettig, F. (2012). Prediction during language processing is a piece of cake—But only for skilled producers. *Journal of Experimental Psychology: Human Perception and Performance, 38*(4), 843-847.

Martin, C. D., Thierry, G., Kuipers, J. R., Boutonnet, B., Foucart, A., & Costa, A. (2013). Bilinguals reading in their second language do not predict upcoming words as native readers do. *Journal of Memory and Language, 69*(4), 574–588.

Mishra, R. K., Singh, N., Pandey, A., & Huettig, F. (2012). Spoken language-mediated anticipatory eye movements are modulated by reading ability: Evidence from Indian low and high literates. *Journal of Eye Movement Research, 5*(1), 1–10.

Miyake, A., & Shah, P. (1999). *Models of working memory: Mechanisms of active maintenance and executive control*. Cambridge, UK: Cambridge University Press.

Myers, J. L., & O'Brien, E. J. (1998). Accessing the discourse representation during reading. *Discourse processes*, 26(2-3), 131-157.

Nation, K., Marshall, C. M., & Altmann, G. T. (2003). Investigating individual differences in children's real-time sentence comprehension using language-mediated eye movements. *Journal of Experimental Child Psychology, 86*(4), 314–329.

Otten, M. (2008). *Discourse-based lexical anticipation: the nature and contextual bias of predictions in language comprehension*. Doctoral thesis, University of Amsterdam.

Otten, M., & Van Berkum, J. J. (2007). What makes a discourse constraining? Comparing the effects of discourse message and scenario fit on the discourse-dependent N400 effect. *Brain Research, 1153*, 166–177.

Otten, M., & Van Berkum, J. J. (2009). Does working memory capacity affect the ability to predict upcoming words in discourse? *Brain Research, 1291*, 92–101.

Peelle, J. E., Troiani, V., Wingfield, A., & Grossman, M. (2009). Neural processing during older adults' comprehension of spoken sentences: age differences in resource allocation and connectivity. *Cerebral Cortex, 20* (4), 773-782.

Pickering, M. J., & Garrod, S. (2013). An integrated theory of language production and comprehension. *The Behavioral and Brain Sciences, 36*(4), 329–47.

R Core Team. (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from http://www.R-project.org/

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*(3), 403.

Salthouse, T. A. (2000). Aging and measures of processing speed. *Biological Psychology, 54*(1), 35–54.

Swaab, T. Y., Ledoux, K., Camblin, C. C., & Boudewyn, M. (2011). ERPs and language processing. In S. J. Luck & E. S. Kappenman (Eds.), *Oxford handbook of event-related potential components* (pp. 387–439). New York: Oxford University Press.

Van Berkum, J. J. a, Brown, C. M., Zwitserlood, P., Kooijman, V., & Hagoort, P. (2005). Anticipating upcoming words in discourse: evidence from ERPs and reading times. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 31*(3), 443–467.

Vos, S. H., Gunter, T. C., Kolk, H. H., & Mulder, G. (2001). Working memory constraints on syntactic processing: An electrophysiological investigation. *Psychophysiology, 38*(01), 41–63.

Wicha, N. Y. Y., Moreno, E. M., & Kutas, M. (2003). Expecting Gender: An Event Related Brain Potential Study on the Role of Grammatical Gender in Comprehending a Line Drawing Within a Written Sentence in Spanish. *Cortex, 39*(3), 483–508.

Wicha, N. Y. Y., Moreno, E. M., & Kutas, M. (2004). Anticipating words and their gender: an event-related brain potential study of semantic integration, gender expectancy, and gender agreement in Spanish sentence reading. *Journal of Cognitive Neuroscience, 16*(7), 1272–88.

Wlotko, E. W., & Federmeier, K. D. (2012). Age-related changes in the impact of contextual strength on multiple aspects of sentence comprehension. *Psychophysiology, 49*(6), 770–785.

Wlotko, E. W., & Federmeier, K. D. (2015). Time for prediction? The effect of presentation rate on predictive sentence comprehension during word-by-word reading. *Cortex, 68*, 20-32.

Wlotko, E. W., Federmeier, K. D., & Kutas, M. (2012). To Predict or Not to Predict: Age-Related Differences in the Use of Sentential Context. *Psychology and Aging, 27*(4), 975–988.

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin, 123*(2), 162-185.

Appendix. Experimental stimuli.

All experimental stimuli along with the cloze probability values for the expected nouns in these sentences are given below. For clarification, the target determiners and nouns are presented in upper case; in the experiment they were lower case.

N	First sentence. Second sentence expected/unexpected version.	Cloze
1	De laatste tijd heeft Victor wat moeite met het lezen van kleine lettertjes. Gelukkig heeft hij DE mooie simpele LEESBRIL/HET mooie simpele VERGROOTGLAS om hem daarbij te helpen.	.93
2	Blij liep de boswachter met zijn kettingzaag door het donkere woud. Hij stopte bij DE oude grote BOOM/HET oude grote HEKWERK midden in het bos en ging aan de slag.	.73
3	Annet had in de zomer te veel zon op haar terras om buiten te zitten. Zij kocht DE grote elegante PARASOL/HET grote elegante ZONNESCHERM bij de praxis zodat ze niet zo snel zou verbranden.	.73
4	Dennis wil Diewertje vanavond ten huwelijk vragen. Dennis heeft DE prachtige en zeer kostbare RING/HET prachtige en zeer kostbare SIERAAD voor zijn aanstaande bruid bij zich.	.87
5	Ik ben graag op de hoogte van het nieuws. Daarom ontvang ik elke dag DE dure maar degelijke KRANT/HET dure maar degelijke DAGBLAD en verscheidene internationale tijdschriften.	.93
6	Nadat hij uren naar het lege doek had gekeken voelde de schilder inspiratie opkomen. Hij greep naar DE intensief gebruikte KWAST/HET intensief gebruikte PENSEEL en smeet de verf op het doek.	.67
7	De misdadiger is opgepakt en veroordeeld en moet nu drie jaar zitten. Hij zit dag en nacht in DE verouderde en oncomfortabele CEL/HET verouderde en oncomfortabele GEVANGENHUIS maar komt binnenkort vrij.	.80
8	De boerin stond vroeg op om de dieren te melken. Zij zette haar krukje neer bij DE onrustige maar kleine KOE/HET onrustige maar kleine GEITJE en begon met haar werk.	1
9	Huilend maakte Floor haar zus wakker. Ze had weer DE nare zeer bloederige NACHTMERRIE/HET nare zeer bloederige VISIOEN gehad en moest getroost worden.	.67
10	Ik heb al slingers en kaarsjes gekocht voor mijn verjaardag. Nu nog DE lekkere niet al te dure TAART/HET lekkere niet al te dure WIJNTJE en het feest is compleet.	.80
11	Andre zat met een krantje en een kopje koffie, maar zonder vervoersbewijs in de trein. Hij zag DE wakkere net iets te ijverige CONDUCTEUR/HET wakkere net iets te ijverige CONTROLETEAM en pakte snel zijn spullen.	.93
12	Sylvia leed aan een acute en zeer zware depressie. Zij werd doorverwezen naar DE begripvolle en behulpzame PSYCHIATER/HET begripvolle en behulpzame CRISISTEAM van het academisch ziekenhuis.	.87
13	De stoere motorrijder hechtte veel waarde aan zijn veiligheid. Hij droeg DE unieke felgekleurde HELM/HET unieke felgekleurde MOTORPAK van zijn motorclub als hij ging rijden.	.87

14	Lieke heeft geen zin in de vele vette gerechten op de kaart. Daarom neemt ze DE lekkere maar wel lichte SALADE/HET lekkere maar wel lichte VOORGERECHT gevolgd door een schotel van gegrilde groente met tahoe.	.93
15	Duncan hechtte veel waarde aan de tradities van zijn schotse voorouders. Bij officiele gelegenheden droeg hij DE oude traditionele KILT/HET oude traditionele ZWAARD van zijn familie.	.87
16	Patrick vond het heel erg om van een uitkering te moeten leven. Hij was op zoek naar DIE ene niet al te complexe BAAN/DAT ene niet al te complexe BEDRIJF om zelf geld te verdienen.	.67
17	Jannie ging naar de oogarts omdat ze ontzettende hoofdpijn had. Nu heeft ze DIE leuke hippe BRIL/DAT leuke hippe MONTUUR die ze gezien had gekocht en dat helpt prima.	.67
18	Janneke kwam net onder de douche vandaan. Ze pakte DE grote iets versleten HANDDOEK/DE grote iets versleten BADLAKEN zodat ze zich af kon drogen.	1
19	Mijn auto moest weer eens gerepareerd worden. Ik ging naar DE nieuwe integere GARAGE/HET nieuwe integere BEDRIJF om de hoek omdat ik zelf niet zo handig ben.	.87
20	Leonard had na wat gepruts de flitser van het toestel weer aan de praat. Hij maakte DE opzienbarend leuke FOTO/HET opzienbarend leuke KIEKJE van de familie waar iedereen het nog jaren over zou hebben.	.80
21	De tv-kok had de suiker en bloem reeds afgewogen klaarstaan. Hij deed alles in DE grote niet zo diepe KOM/DE grote niet zo diepe BORD en gooide een flinke scheut rum erbij.	.80
22	Ik gooi nooit rommel op straat. Ik zoek altijd DE meest dichtbijzijnde PRULLENBAK/HET meest dichtbijzijnde VUILNISVAT op en anders stop ik het in mijn zak.	.93
23	John kon met geen mogelijkheid de nieuwe auto zelf betalen. Hij nam DE langlopende voordelige LENING/HET langlopende voordelige KREDIET omdat hij de auto wel heel leuk vond.	.80
24	De trotse vader wilde de bruiloft van zijn dochter vastleggen. Hij had DE kleine compacte VIDEOCAMERA/HET kleine compacte FOTOTOESTEL in zijn hand maar was te ontroerd om deze te hanteren.	.93
25	Herman was nog nooit in Frankrijk geweest en wist de weg dus niet. Hij kocht DE uitgebreide michelin KAART/HET uitgebreide michelin STRATENBOEK voor zijn zus zodat zij de weg kon wijzen.	.67
26	De gelovige vrouw voelde een plotselinge aandrang om te biechten Zij ging naar DE uitermate moderne KERK/HET uitermate moderne GEBEDSHUIS om vergeving te vragen voor haar zonden.	.80
27	Mijn kat was weer eens op jacht geweest. In de gang lag DE schattige bruine MUIS/DE schattige bruine MUSJE die ik al eerder in de keuken gezien had dood op zijn rug.	.60
28	Koning Edward de vierde viel in 1374 het kasteel van Stuart de Bruut aan. Hiermee begon DE vijftienjarige OORLOG/HET vijftienjarige CONFLICT waarbij vele mannen stierven.	.73
29	Jos had het helemaal gehad met de vertragingen en overvolle treinen. Hij kocht DE handige kleine AUTO/HET handige kleine BUSJE van zijn buren omdat zij hem toch bijna niet gebruikten.	.93

30	Nadat Maya was afgestudeerd spitte zij elke zaterdag alle kranten door. Zij was op zoek naar DIE ene uitdagende BAAN/DAT ene uitdagende BEDRIJF waarin zij al haar talenten kwijt kon.	.60
31	Johan had zich al een week niet geschoren. Hij had DIE stoppelige charmante BAARD/DAT stoppelige charmante SIKJE waar vrouwen wild van werden.	.60
32	Door de recessie was Antonio ineens werkeloos. Hij kreeg DE kleine maar wel afdoende UITKERING/HET kleine maar wel afdoende PENSIOEN waarmee hij in zijn levensonderhoud kon voorzien.	.73
33	Annelies had wel zin in wat wijn bij het eten. Ze pakte DE kleine exclusieve FLES/HETE kleine exclusieve VAT witte wijn uit de koelkast.	.60
34	De secretaresse legde de brief opzij en printte de belangrijke overeenkomst uit. Ze deed hem in DE witte discrete ENVELOP/HET witte discrete MAPJE en legde hem in het postvakje van de accountant.	.73
35	Jeff ging naar de dokter omdat hij bang was dat hij hiv had. Hij wilde DE meest betrouwbare TEST/HET meest betrouwbare ONDERZOEK die er toen bestond laten doen voor zijn gemoedsrust.	.67
36	Theresa dacht dat wat groen haar kamer wel zou opfleuren. Daarom kocht ze nu DE leuke frisgroene PLANT/HET leuke frisgroene BONSAIBOOMPJE in het leuke potje.	.73
37	Jenny zag dat de plantjes water nodig hadden. Ze pakte DE kleine plastic GIETER/HET kleine plastic KANNETJE en ze vulde deze bij de kraan.	.93
38	Marieke had epilepsie. Zij kreeg regelmatig DE meest vervelende epileptische AANVAL/HET meest vervelende epileptische INSULT omdat ze niet goed reageerde op de normale medicijnen.	.73
39	De actrice had een prachtige jurk aan maar ze vond haar hals nog wat sober. Ze pakte DE verfijnde glinsterende KETTING/HET verfijnde glinsterende COLLIER om het geheel af te maken.	.73
40	Dit college zou Marleen haar tentamen terug krijgen. Ze hoopte op DIE flink hoge VOLDOENDE/DAT flink hoge CIJFER zodat ze voldoende punten had om de cursus af te ronden.	.80
41	Hanna vertelde de nachtzuster dat ze het zo koud had. Ze kreeg van de lieve zuster DE niet zo warme DEKEN/HET niet zo warme DEKBED voor de nacht en dat was voldoende.	.67
42	De Aboriginal hield op zijn ranch een aantal typisch Australische dieren. In een groot buitenhok zat DE behoorlijk levendige KANGOEROE/HET behoorlijk levendige BUIDELDIER veel lawaai te maken.	.67
43	Die avond hadden de vriendinnen geen zin om zelf te koken. Ze bestelden DE goedkope maar niet lekkere PIZZA/HET goedkope maar niet lekkere GERECHT bij de pizzeria omdat hun vaste afhaaltent gesloten was.	.87
44	Het jonge stel ging op huwelijksreis naar Egypte. Ze bezochten DE eeuwenoude PIRAMIDE/HET eeuwenoude BOUWWERK op weg naar hun luxe hotel.	.80
45	Julia was bang dat de dure juwelen van haar overleden oma gestolen zouden worden. Ze ging op zoek naar DE meest onbereikbare KLUIS/HET meest onbereikbare DEPOT om de sieraden in op te bergen.	.80
46	De keuken die Alex zelf had verbouwd was bijna af, het was er alleen nog erg donker. Hij kocht DE interessant ontworpen LAMP/HET interessant ontworpen SPOTJE van die beroemde designer voor boven het aanrecht.	.87

47	Jessica wilde er verpletterend uitzien op de reunie van haar middelbare school. Ze kocht DE meest opvallende JURK/HET meest opvallende MANTELPAK van die ontwerper die toen helemaal in was en viel een paar kilo af.	.87
48	Het was onverwacht toch een hele late avond geworden en de bussen reden niet meer. Jaqueline nam DE betrouwbaar uitziende TAXI/HET betrouwbaar uitziende TAXIBUSJE om naar huis te gaan.	.87
49	De juwelier voelde zich nooit echt veilig in zijn winkel. Hij was vooral bang sinds DE erg agressieve OVERVAL/HET erg agressieve OPSTOOTJE door een gewelddadige bende die de buurt terroriseerde.	.73
50	De directeur vond dat het bestuur bij elkaar moest komen om de kwestie te bespreken. Hij plande DE hopelijk nuttige VERGADERING/HET hopelijk nuttige OVERLEG voor volgende week donderdag.	.73
51	Het meisje was nog te klein om in de snelle attracties van de kermis te gaan. Ze mocht wel in DE best ouderwetse DRAAIMOLEN/HET best ouderwetse REUZENRAD maar niet in de botsautootjes.	.73
52	Anne en Marijtje wilden graag naar de nieuwe film die zo lovend werd besproken. Ze bezochten DE leuke en sfeervolle BIOSCOOP/HET leuke en sfeervolle FILMHUIS waar ze nog ouderwets lekkere popcorn verkochten.	.80
53	Sneeuwwitje wist niet dat de appel eigenlijk giftig was. Ze nam DE lekker sappige HAP/HET lekker sappige PARTJE van de aantrekkelijke vrucht en viel neer.	.80
54	De mooie vrouw zwom in de zee, nietsvermoedend over het loerende gevaar. In het water zat namelijk DE grote gevaarlijke HAAI/HET grote gevaarlijke DIER te wachten op zijn prooi.	.73
55	In de winter kon de gymles natuurlijk niet buiten worden gegeven. Daarom had de school DE ruim ingerichte ZAAL/HET ruim ingerichte SPORTLOKAAL erbij laten bouwen.	.67
56	Kate was aan het koken en ze sneed per ongeluk in haar vinger. Ze deed DE nieuwe effectieve PLEISTER/HET nieuwe effectieve MEDICIJN op de wond na hem ontsmet te hebben.	.80
57	De dappere ridder zag dat de draak de goede tovenaar bedreigde. Hij pakte snel HET oude vetrouwde ZWAARD/DE oude vetrouwde LANS en doodde de draak.	.93
58	Anne had eindelijk een rustig plekje gevonden waar ze kon studeren. Ze ging zitten en pakte HET behoorlijk zware BOEK/DE behoorlijk zware ROMAN uit haar tas.	.67
59	Anette vond haar kamer een beetje muf ruiken. Zij opende HET piepende hoge RAAM/DE piepende hoge DEUR zodat haar fijne kamer kon luchten.	.93
60	Het kleine kind had het warm en liep te zeuren. Ze wilde HET lekker koude IJSJE/DE lekker koude DRANK om af te koelen.	.67
61	De politie moet de moordverdachte laten gaan. Ze hebben nog niet HET unanieme BEWIJS/DE unanieme REDEN gevonden dus de zaak blijft onduidelijk.	.60
62	De machinist remde de trein vol ongeduldige forenzen alvast wat af. Hij naderde HET netjes opgeknapte STATION/DE netjes opgeknapte WISSEL met een heel redelijke snelheid.	.73
63	Dana heeft in de ochtend niet echt honger. Ze neemt nooit HET door moeder klaargemaakte ONTBIJT/DE door moeder klaargemaakte BOTERHAM omdat ze daar misselijk van wordt.	.87

64	Hessel was bang dat zijn nieuwe fiets gestolen zou worden uit de niet zo goed beveiligde stalling. Hij kocht HET aanbevolen dure SLOT/DE aanbevolen dure KETTING zodat hij zijn rijwiel stevig vast kon zetten.	.87
65	De goochelaar had een hoge hoed op en een gouden toverstok in zijn hand. Hij haalde HET nogal bange KONIJN/DE nogal bange DUIF tevoorschijn uit zijn mouw.	.80
66	Nadat zij van het gezegende water had gedronken was de kreupele genezen. Het was HET eerste echte WONDER/DE eerste echte VERRASSING sinds jaren in Lourdes.	.93
67	Roland verzamelde al het droge hout in de buurt van de tent. Hij maakte HET behoorlijk warme KAMPVUUR/DE behoorlijk warme VUURKORF aan voor ons.	1
68	Tijdens mijn wereldreis hield ik regelmatig contact met het thuisfront. Ik zat vaak in HET enige vindbare INTERNETCAFE/DE enige vindbare BELWINKEL van de stad en de verbinding was vaak traag.	.87
69	De herder telde zijn dieren nogmaals. Hij miste HET kleine zwarte SCHAAP/DE kleine zwarte GEIT en dat zou zijn baas niet leuk vinden.	.67
70	De arme ridder woonde tegen zijn zin in een eenvoudig hutje. Hij droomde van HET duur ingerichte KASTEEL/DE duur ingerichte VESTING van de machtige koning en vond zijn hutje veel minder mooi.	.60
71	De student stond die ochtend opmerkelijk vroeg op. Hij had die dag HET algemeen verplichte TENTAMEN/DE algemeen verplichte WERKGROEP en hij wilde niet te laat komen.	.67
72	John en Rosa hadden afgesproken om nog een biertje te gaan drinken. Ze gingen naar HET altijd drukke CAFE/DE altijd drukke PUB waar ze verschillende bieren op de tap hadden.	.60
73	Jan zag dat hij de gipsplaten nog op maat moest maken. Hij pakte DE zeer scherpe ZAAG/HET zeer scherpe STANLEYMES om de ruwe kantjes eraf te halen.	.80
74	Renate wilde graag een appeltaart bakken, maar wist niet hoe. Ze vond HET simpele en duidelijke RECEPT/DE simpele en duidelijke RECEPTUUR voor een taart met appel en noten op internet.	.93
75	Jesper wilde heel graag naar het nieuwe toneelstuk van Carice van Houten. Hij had HET nogal exclusieve KAARTJE/DE nogal exclusieve PLAATS gekregen van zijn lieve vriendin.	.60
76	Het rommelhok was door een stylist omgetoverd tot een logeerkamer. In het midden stond HET met stof beklede BED/DE met stof beklede SLAAPBANK waar de stylist behoorlijk trots op was.	.73
77	De voetballers vierden de goede afloop van hun wedstrijd in het cafe. Ze namen allemaal HET lekkerste speciale BIERTJE/DE lekkerste speciale PILS van de tap voordat ze weer naar huis fietsten.	.93
78	Irene zag dat de melk was overgekookt. Ze pakte HET schone gele DOEKJE/DE schone gele SCHUURSPONS om de vieze boel op te ruimen.	.73
79	De jonge reizigers stonden in de rij bij de douane. Iedereen had HET twee jaar geldige PASPOORT/DE twee jaar geldige REISPAS bij hem ingeleverd, zodat ze snel konden doorlopen.	.60
80	Mijn vriend en ik willen onze verjaardag gezamenlijk maar vooral groots vieren. We geven HET grootste en wildste FEEST/DE grootste en wildste FUIF van het jaar en hopen dat er veel mensen kunnen komen.	.73

81	De schrijver negeerde de slechte kritieken. Hij werkte aan HET veel betere BOEK/DE veel betere ROMAN in de avonduren die hij vrij had.	.60
82	Iedereen dacht dat Jeroen het niet ver zou schoppen als kok, maar hij zette door. Hij werkt nu bij HET zeer populaire RESTAURANT/DE zeer populaire ZAAK waar veel beroemde mensen komen.	.80
83	De voortvluchtige dader was absoluut geen onbekende bij de politie. Hij had HET meest indrukwekkende STRAFBLAD/DE meest indrukwekkende REPUTATIE van het land en werd beschouwd als levensgevaarlijk.	.73
84	De bruidegom zag er fantastisch uit. Hij droeg HET best opvallende PAK/DE best opvallende SMOKING van een soepele grijze stof met een zachtgele stropdas.	.67
85	Al van jongs af aan wilde Reinier acrobaat worden. Hij werkt nu bij HET grote reizende CIRCUS/DE grote reizende THEATERSHOW dat zeer goed bekend staat, als trapeze artiest.	.93
86	Jozefien wilde de stekker van de stofzuiger inpluggen in de slaapkamer. Ze zocht HET handig geplaatste STOPCONTACT/DE handig geplaatste STEKKERDOOS om ook de hal te kunnen zuigen.	1
87	De leraar probeerde de verveelde pubers iets uit te leggen. Hij schreef op HET ietwat gammele SCHOOLBORD/DE ietwat gammele FLIP-OVER en praatte tegelijkertijd.	.80
88	Jan en Marie hadden heel erg gehoopt dat hun derde kind een jongen zou zijn. Ze kregen HET hele mooie MEISJE/DE hele mooie MEID met de prachtige bruine ogen, en daar waren ze ook gelukkig mee.	.80
89	Rian en Lieke gingen liever een roseetje drinken dan studeren nu het zo warm was. Ze zaten de hele middag op HET op de gracht uitkijkende TERRAS/DE op de gracht uitkijkende BOOT te genieten van de zon.	.93
90	Jan had een behoorlijk ouderwetse mening over vrouwen. Die horen volgens hem achter HET klassieke stenen AANRECHT/DE klassieke stenen KOOKPLAAT te staan en geen carriere te hebben.	.73
91	Ongedurig stonden de vrijgezelle vrouwen te wachten totdat de bruid eindelijk ging gooien. Uiteindelijk wierp zij HET zeer kleurrijke BOEKET/DE zeer kleurrijke BOS in de gillende menigte.	.80
92	De kleine Noa wilde elke avond door zijn vader voorgelezen worden. Hij kon niet slapen zonder HET soms spannende VERHAALTJE/DE soms spannende VERTELLING uit het voorleesboek te hebben gehoord.	.87
93	De kok had een mooie verse zalm gekocht die hij nu ging fileren. Hij pakte HET Japanse handige MES/DE Japanse handige PLANK en ging vervolgens aan de slag.	.93
94	Mijn moeder had net een dure nieuwe eettafel gekocht en was bang voor krassen. Ze legde meteen HET extra dikke KLEED/DE extra dikke MAT voor me op tafel neer.	.73
95	Mijn oma en opa zijn erg religieus. Naast hun bed hangt HET nogal dramatische KRUIS/DE nogal dramatische CRUCIFIX van licht essenhout dat mijn grootvader heeft gekregen van zijn vader.	.73
96	Zijn moeder wilde dat Joris eens wat meer las, bijvoorbeeld voordat hij ging slapen. Ze koos HET bekende spannende BOEK/DE bekende spannende RIDDERSAGE over het spook voor hem uit in de winkel.	.80

97	Toen de man thuis een fles champagne opende, schoot de kurk razendsnel omhoog. Zij keken naar HET pas geverfde PLAFOND/DE pas geverfde DAKKAPEL met nu een zwarte vlek.	.73
98	Het verbaasde Charlotte niets toen de koerier van de bezorgservice aanbelde. Ze verwachtte HET belangrijke en dure PAKKET/DE belangrijke en dure BESTELLING uit Amerika.	.60
99	Mark en zijn vrienden gingen een voetbalwedstrijd bekijken. Ze namen de bus naar HET beroemde nieuwe STADION/DE beroemde nieuwe ARENA van het team al vroeg in de ochtend.	.80
100	Max hield van de clowns en de acrobaten die hij op tv zag. Zijn ouders namen hem mee naar HET grootste en beste CIRCUS/DE grootste en beste CARNAVAL in de stad.	.93
101	Het was een prachtige zonnige dag en Thomas en zijn vrienden wilden gaan picknicken. Ze gingen naar HET grote aangename PARK/DE grote aangename SPEELTUIN om daar de middag door te brengen.	.87
102	Anna was al laat voor haar afspraak toen ze erachter kwam dat het advocatenkantoor op de elfde verdieping was. Ze haastte zich naar DE recent gerenoveerde LIFT/HET recent gerenoveerde TRAPPENHUIS aan het eind van de gang.	.80
103	Joep en Sanne wilden gaan samenwonen in een woning met een tuin. De hele zomer zochten zij naar HET mooie maar betaalbare HUIS/DE mooie maar betaalbare STUDIO van hun dromen.	.60
104	Ina studeert volgende week af en ze wil het groots gaan vieren. Ze heeft veel zin in HET gezellig drukke FEEST/DE gezellig drukke BORREL met haar studiegenoten.	.87
105	Jeroen kwam erg moe thuis na een lange dag werken. Hij ging direct naar HET grote comfortabele BED/DE grote comfortabele BANK om een dutje te doen.	1
106	Willem had zich voor een belangrijke afspraak verslapen. Hij had geen tijd voor HET broodnodige voedzame ONTBIJT/DE broodnodige voedzame MAALTIJD dat hij elke ochtend tot zich nam.	.73
107	De groente in de oven lijken gaar te zijn geworden. Jan deed ze op HET nieuwe keramische BORD/DE nieuwe keramische SCHAAL om ze te serveren.	.80
108	Jeroen studeerde al 4 jaar voor piloot en hij had net een baan gevonden. Nu bestuurde hij HET coolste en modernste VLIEGTUIG/DE coolste en modernste HELIKOPTER van de KLM op zijn eerste echte vlucht.	.80
109	Marnix speelt al sinds zijn 5e viool en is ook professioneel muzikant geworden. Nu is hij onderdeel van HET bekendste moderne ORKEST/DE bekendste moderne BAND in Nederland.	.80
110	Tijdens de zware regenbui gisteren, lekte er water uit het plafond van het oude huisje. Er was een reparatie nodig aan HET oude ondichte DAK/DE oude ondichte SCHOORSTEEN waar een beschadiging bleek te zijn.	.87
111	Johan ging elke ochtend vroeg even naar de bakker. Zo had hij elke ochtend HET verse pasgebakken BROOD/DE verse pasgebakken CROISSANT waar hij zo dol op was.	.76
112	De huisarts vond dat Anette een gecompliceerde operatie moest ondergaan. Ze ging naar HET bekendste en bekwame ZIEKENHUIS/DE bekendste en bekwame SPECIALIST voor een uitgebreid lichamelijk onderzoek.	.73